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The Naval Ship Design/Prcduction Interface

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The Naval Ship Design/Production Interface

Abstract

The paper discusses, from a ship designer's perspective, some of the current topics and issues relating to the interface between naval ship design and production. The current environment within which naval ship design activity is taking place is described. Notable current views on Navy ship design and how it might be improved are summarized. Navy design topics pertinent to improving ship producibility, operability, maintainability and survivability are discussed and examples from recent ship designs are presented. Issues which result from apparent conflicts in current design initiatives and critiques of the Navy ship design process are highlighted and discussed. Finally, some general conclusions are drawn.

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1. Introduction

Ship design is an iterative, evolutionary process by which an initially ill-defined need is translated into a detailed data package containing sufficient information to permit ship construction. During this process, nearly as much effort is expended on defining the need or "owner's requirements" as is spent on defining the design which responds to the need. Design occurs in an environment constrained by design standards, i.e. rules established by the design agency itself or invoked on the agency by external regulatory bodies. As design proceeds, there is an exponential increase in the amount of detail defined as well as in the amount of effort required to do so. In order to manage and control the process, it has naturally been divided into phases separated by major review and decision points. There are four design phases in the naval ship acquisition world. They are: feasibility studies, preliminary, contract and detail design. Traditionally, the Navy itself has performed the first three of these phases, ultimately producing a contract design data package consisting of specifications, drawings and other data in sufficient detail to enable competing shipbuilders to prepare bids for the task of developing the detail design and building the ship. For this reason, in the world of naval ships Many people, when they refer to the ship design/production interface, are really referring to the interface between the Navy-dominated early stage design world prior to the completion of contract design and the subsequent shipbuilder-dominated world of detail design and construction. This paper will address this Navy-shipbuilder interface.

At the present time, a great deal of attention is focused on the Navy-shipbuilder interface and a number of initiatives are underway which relate to it. Examples of the attention being paid to the subject include the recent publication of Ref. (1) by the Marine Board of the National Research Council and of Ref. (2), contained in the first issue of the Journal of Ship

Production published by SNAME. Refs. (3) and (4) are also noteworthy. Thus it is appropriate for us to examine the reasons for this greatly increased attention and survey some Navy design topics which are pertinent to it. It will not be possible in this paper to examine any of the topics in great depth. However, a broad survey will point the reader toward appropriate references for further study, as well as increase his understanding of some of the current events and issues relating to the interface between.naval ship design and construction. A -greater understanding of our mutual concerns and the,Navy's present needs will enhance the reader's ability to contribute in various ways to improve our methods and approach and, ultimately, the Naval ships we produce. Our search is for ways to improve productivity and, at the same time, to improve the operability, maintainability and survivability of our naval ships.

2. The Current Design Environment

Any difficult task is as strongly influenced by the environment it is performed in as by the skill and dedication of the performer. The environment not only affects the task approach and the numerous decisions made along the way but also how the final product is judged. Naval ship design is no different. The design environment includes a multitude of interest groups, each of which in turn is influenced by a variable environment, as well as impersonal factors such as design facilities, government regulations and the status of emerging technology. The interest groups which affect the naval ship designer's work include those who establish requirements-t the OPNAV sponsor and his chain of command including the CNO and SECNAV, the Ship Acquisition Manager or SHAPM,. the potential shipbuilders, equipment developers and suppiers, those who will inspect the completed ship (the Board of Inspection and Survey--INSURV), the ultimate users--the Fleet Commands, those who must maintain and modernize the ship over its service life--30

years and increasing!-- and, last but not least, the financial backer--the taxpayer as represented by his Congressman. In contrast to the private sector, notable in this list is the large number of interest groups as well as- the fact that it is not clear who is the customer, i.e. is it the requirements setter--the OPNAV sponsor and his chain of command? the Congress? or the ultimate user, the Fleet? This condition makes the designer's task more difficult. The difficulty is further compounded by the fact that the average tenure of key individuals in each of the interest groups is almost certainly less than half of the time required to design, build and test a new naval ship.

The computer "explosion" is a key element of the current design environment. Everyone recognizes that we must utilize the computer, not only to perform design calculations and "keep the books" but also in linked and interactive modes to facilitate the myriad decisions which must be made to integrate a ship design. Linked computer systems are also necessary to maintain and transfer relevant ship design data electronically between parties as a ship design is developed, the ship is built and tested and, after delivery, is operated, maintained and modernized over its service life. Developing the standards, methodologies and facilities needed to do these things will not be an easy task; the task is made more difficult by the diversity of interested parties and the high rate of change of computer technology.

The Navy has unique requirements which are a major influencing factor on naval ship design but are often neglected by those who preach cost reduction and risk acceptance. These requirements reflect young, often inexperienced, and transient crews and ships with long service lives, unusual operating areas, mission profiles which require the performance of principal ship functions at sea rather than in port and, of course, the need to operate in hostile environments. As Admiral Bulkeley so often reminds us, our ship designs must

support the Fleets' ability to perform the Navy's mission: "...Prompt, sustained. . . combat operations at sea."

As is well known, today the commercial ship segment of the nations' shipbuilding business is nearly extinct and there are no signs of an early revival. The Navy workload is insufficient to adequately task all of nation's major shipbuilders. As a result, many are barely surviving and the competition for available work is desperate. It is also widely recognized that the productivity of our nation's shipbuilders-is generally low in comparison to that of the Japanese and better European shipyards.

Pressure to reduce ship cost is increasing as it becomes harder to reach the Administration's goal of a 600 ship Navy in the face of Congressional budget cuts. Ref. (5) presents the Navy plan for acquisition streamlining to save money and thus "not compromise our ability to provide the Fleet with the quantity and quality of weapons systems needed."

NAVSEA resources for performing ship design are also constrained. Space is the most critical problem. The National Center building complex which is NAVSEA's home is overcrowded. There is no space available to assemble collocated design teams. This can only be done by a "force fit", i.e. by displacing people and further compressing the work force. Personnel numbers are also constrained and, in the Engineering Directorates, the manpower available to do ship design is effectively decreasing as management imposes additional engineering duties in the areas of ship construction support and Fleet maintenance and modernization. Computing facilities are only marginally adequate today and there are overwhelming obstacles to computer upgrades both in the procurement process and installation-wise, Space is virtually impossible to find and the lead times and administrative

obstacles involved in obtaining necessary support services in our leased buildings, e.g. air conditioning and electricity, would be literally unbelievable to an outsider.

Finally, the Navy leadership is currently pressing the ship design and engineering community to do a more thorough and professional job of ship engineering. Increased emphasis is being placed on design for ship operability, maintainability and survivability. More effort is being expended on these aspects in our ship designs and top level design reviews have become more frequent and more intense. In part, this is a reaction to past deficiencies; in part it is in recognition of increased future threats.

3. Current Views Affecting Navy Ship Design

Ref. (1) is an excellent report summarizing an exhaustive study into ways by which naval shipbuilding could be made more productive. The Report makes a number of recommendations, some of which are directly pertinent to the current naval ship design process and others less so. A few of the most pertinent findings and recommendations are paraphrased here:

a. Educate Navy engineers in zone-oriented ship construction technology so that Navy practices and procedures can be adapted in support of it.

b. Develop the means to apply zone-oriented ship construction technology in the preliminary and contract design phases, i.e., incorporate production considerations.

C. Minimize the number of contract, i.e. non-deviation drawings, in the bid package. When contract drawings are used, be sure they reflect production considerations.

d. Consider a change in contract design (CD) emphasis based on the shipbuilder's data requirements under the zone-oriented construction approach, i.e. greater emphasis on systems design and equipment selection; less on structural design and ship arrangement details.

e. Produce a firmer design baseline at the end of CD.

f. Create producibility and manufacturing cost design guides to aid prelimina and contract design teams to develop more producible and cost effective designs.

g* Reflect lead and follow yards' inputs in the contract design, e.g. facilities, suppliers, and production methods, to avoid extensive rework (note that necessary design compromises could preclude either yard from obtaining maximum productivity).

h. Establish a task force on computerization in concert with the shipbuilding design and supplier industries to employ electronic media to a maximum extent in design, construction, management and life-cycle support in the next generation of naval ships.

i. Invest more resources in standards development. Convert military specifications to commercial standards wherever appropriate, accelerate the MILSPEC improvment program and use proven foreign or international design standards, to the extent feasible, as the technical basis for U.S. national shipbuilding standards to minimize our own effort.

j. Adjust GFI and GFE schedules during detail design and construction to suit the zone-oriented approach; GFI will 'generally be needed earlier and GFE later than previously. Implement phased issue of GFI.

In Ref. (4) concerning acquisition streamlining, the following points pertinent to the Navy approach to ship design are made:

a. Don't over specify; assume additional justifiable risks.

b. Tailor specifications and contract requirement documents; use a "clean sheet of paper" approach; question all requirements; eliminate the automatic chain-referencing of lower tier specifications; minimize "how to" specifications and emphasize performance requirements.

C. Involve industry in the early design and requirements development phases.

d. Avoid premature setting of requirements; remain open to cost saving options.

Ref. (3) reports upon the Navy's Board of Inspection and Survey's (INSURV'S) findings regarding Fleet characteristics that are the result of past Navy design engineering efforts. Recommendations are made regarding requirements for the engineering of characteristics that support the Fleets' ability to conduct the Navy's mission "... Prompt, sustained...combat operations at sea." The following points are excerpts from the paper:

a. The most rewarding aspect of the recent INSURV design reviews has been the conclusion that once again the General Specifications for Ships of the United States Navy (Gen Specs) play a central role in the development of today's detail ship specifications for Navy ships. The detail specifications for the LHD closely reflect the requirements contained within the Gen Specs. Compared to the loosely written performance specifications used for the LHA-1 Class, the LHD detail specifications represent a marked improvement.

b. Industry will not improve their products until the Navy tells what it wants with well-engineered specifications. Contractors seldom rise above the level of excellence of the engineering inherent in the contract specifications.

C. Navy engineers should conduct warship design through contract design using Gen Specs as the basis for the ship specifications.

d. Engineering feedback is an essential part of the design and engineering process. Testing and correcting deficiencies found during testing is an important part of the engineering process. Classic engineering requires feedback from the user to the responsible engineer regarding the performance of the equipment or system in question.

e. Ship equipments and systems should be selected with operational effectiveness and reliability in mind; then designed into the ship in a manner that does not compromise that reliability; then tested to validate that operational reliability is present.

f. The Navy should be concerned regarding the survivability of all ships. Ships acquired to "commercial standards" are a special concern because they lack not only weaponry for basic defense, but also important features that reduce the consequences of damage. It cannot be guaranteed that such ships will not sustain damage from attack or accident and, therefore, consideration must be given to providing a reasonable package of features to improve survivability. New sealift assets (MSC fast support ships and prepositioned charters) are of concern particularly in view of the dollar value of the assets they will carry.

g More and better maintenance capability engineering should be a feature of future Navy ship designs.

h. Maintenance capability requirements (i.e. accessibility, test equipment stowage, I.C. circuit availability and documentation for alignment, test operations and maintenance) should be clearly visible in the specifications.

i. Space reservations for maintenance access, as well as test equipment and special tool stowage, should be clearly delineated on contract drawings.

Finally, Ref. (6) defines NAVSEA's long range objectives for Hull, Mechanical and Electrical (HM&E) Engineering. The following excerpt is relevant:

"NAVSEA 05 (the Ship Design and Engineering Directorate) will control and be fully responsible for the following throughout the life of a ship:

a. Design

Initial design of the ship and its HM&E systems, including system descriptions, component specifications, shipbuilding specifications, and other technical descriptions. During detail design, and acquisition phases, NAVSEA 05 is to exercise increased technical control through review and approval of key drawings, critical equipment purchase specifications, shipbuilding specification modifications and deviations, etc., to ensure that design standards and requirements are being met by the shipbuilder."

Clearly the recommendations cited in these references reflect a diversity of opinion with respect to what is required to improve our design/production capability. Equally as clearly they identify approaches which collectively contain contradictory guidance which makes it impossible to satisfy everyone.

4. Some Pertinent Navy Desiqn Topics

The following paragraphs briefly describe selected NAVSEA programs or policies which relate to the naval ship design/production interface and are pertinent either to the enhancement of ship producibility or to the recent increased emphasis on improving ship operability, maintainability and survivability.

Education of Navy Personnel

At presen't there are no formal programs in the Washington area to train NAVSEA engineers and managers in zone-oriented construction technology and its implications for Navy ship design and acquisition procedures. Many of our engineers and managers have, however, received informal, on-the-job training in this subject in the course of their daily work through their close relationships with, including frequent travel to, shipyards employing such techniques. New engineering recruits to the Ship Design and Engineering Directorate (SEA 05) spend 18 months in a training program, six month of which is field training. Typically three of the six months are spent in a shipyar albeit often a naval shipyard doing repair or modernization work. We also send worki level engineers on one year long term training assignments to private shipyards to study modern ship detail design and construction techniques. In recent years, three engineers have been so trained--one each at Bath Ironworks, Todd !A and NASSCO. Other, special training assignments are often made. For example, a structural engineer was recently sent to the United Kingdom for six months to learn modern GRP hull design and fabrication practices in connection with a new minesweeper design.

In 1982, NAVSEA entered into an agreement with the University of Michigan to establish, within the Department of Naval Architecture and Marine Engineering, a NAVSEA Cooperative Research Program and professorial position in Shipbuilding Technology. One result of this Program has been the development of a curriculum

in the area of shipyard planning, production engineering, and ship design for producibility. Several NAVSEA engineers have taken these courses while attending the University of Michigan for advanced training in naval architecture. Other graduates of the courses have since taken jobs at naval shipyards or other Navy activities.

As a result of the promulgation of Ref. (6) and its emphasis on improved ship operability, a new in-house course is being presented to acquaint our engineers with Human Factors Engineering and how to apply it in the design process. In the same vein, many of our design engineers have attended a two-week summer course in Ship Protection and Weapons Effects. Many other short and long term training opportunities are available, including graduate level courses thru our own NAVSEA Institute.

Shipbuilder Involvement in Design

For at least the past 16 years, shipbuilders have participated in the contract design, and sometimes earlier design stages, of most, and all major, Navy ships. The thrusts behind this participation have been to incorporate producibility considerations into the completed contract design, to gain insight into the shipbuilders' interpretation of specification language, to assign design and/or cost estimating tasks to the builders where their special expertise would prove beneficial and to have additional "pairs of eyeballs" reviewing and critiquing the developing design. The methods employed to obtain shipbuilder involvement fall into the six basic strategies listed below; each has several variants. The first four of these strategies apply to Navy designs: designs controlled and directed by the Navy on a day-to-day basis. The last two strategies apply to industry designs in which the Navy role is restricted to establishing top level requirements and evaluation of the proposed industry designs.

(1) Award support contracts to one or more competitively selected shipbuilders one of whom may be in a favored position to receive the lead ship detail design and construction (DO&C) contract. The selected builders participate in the Navy design effort. Restrict negotiations for the DD&C contract to these shipbuilders. This general approach was used for FFG-7, the Sea Control ship (never built) and, more recently, the MCM and DOG-51, as well as many other designs.

(2) Pay selected builders modest sums to review and critique the Navy design and perform special studies they volunteer for (T-A0 187 approach).

(3) Invite all interested shipbuilders to participate in the Navy design effor at their own expense, either as working members of the design team or in a review-critique capacity at key design milestones. This approach is currently being employed on the SWATH T-AGOS design effort where ten prospective builders are each providing the equivalent of one full time designer to the team. All prospective builders are also invited to participate in design reviews and generally critique the design as it evolves. On the recent AOE-6 design, seven shipyards participated in a reviewing capacity only.

(4) Pay one or more builders to do the contract design under Navy direction (selected either competitively or on a sole source basis) and then negotiate with them for the lead ship detail design and construction contract. This general approach has been used for complex warships such as nuclear powered aircraft carriers and submarines; also for the LHD-1 design--a modified repeat.

(5) The A-109 approach--a competitive, multi-phase, industry design approach from the outset whereby the number of competitors is selectively decreased as the design evolves through several phases. This approach has been used for the LCAC and MSH designs.

(6) The Z-step approach whereby all interested shipbuilders respond to a Navy Circular of Requirements with preliminary/contract designs and detail design and construction proposals developed at their own expense. The proposals are evaluated and a detail design and construction contract is awarded to the lowest bidder whose design and proposal meets all stated Navy requirements. This approach has been used for a number of recent designs , especially conversions and T-ships.

The following paragraphs describe the involvement of shipbuilders in five of our recent design projects.

<u>T-A0 187</u>

A shipbuilder review was conducted for the T-A0 187 program between February and June 1982 before the final reading session and signature of the contract package. Proposals for this review were solicited and the following six shipbuilders were each awarded firm fixed price contracts:

Avondale Shipyards
Levingston Shipbuilding
Newport News Shipbuilding & Drydock Co.
General Dynamics Corp., Duincy
National Steel and Shipbuilding Co.
Bethlehem Steel Co., Sparrows Point

The criteria for award of review contracts were based on the physical ability of the proposer to construct the ship.

The shipbuilders were specifically tasked to accomplish the following:

(1) Review the specs and drawings for errors, ambiguities, and conflicts

(2) Suggest cost reduction items

(3) Suggest improvements for producibility

(4) Suggest further commerciality items.

Though not specifically tasked, some of the shipbuilders asked and were permitted to submit alternate design proposals, e.g. alternate propulsion plants. However, none of the alternates proposed were accepted.

The review was not considered by the Navy to be completely successful for two reasons: (1) the review was unstructured in that the shipbuilders could comment on any system at any time during the review; this greatly complicated the NAVSEA respon mechanisms, (2) the Navy contract design package submitted for review was immature a incomplete. Eventually over 4000 comments were received which proved to be an unmanageable quantity to adjudicate in the short time available. In general, the review aided the Navy effort to correct discrepancies between specification sections and the contract drawings, which would have occurred to some extent without the revi No major design changes were proposed or adopted as a result of this review. Howeve the winning shipbuilder, Avondale, has stated that the review period allowed them time to become very familiar with the ship design which aided the bidding process and allowed them to start detailed design efforts earlier.

AOE-6.

Seven shipbuilders have been involved in the AOE-6 design by their voluntary no-cost participation in a detailed review of the ship specifications, contract

drawings and CDRL (data requirements package) which will eventually make up the final contract design package for the ship. The package was given to the participating shipbuilders in its later stages of development so that the shipbuilders could concentrate on producibility and cost reduction items rather than on technical errors in the package.

The reviews were structured over a 3-month period. In each of the functional areas, major systems were defined and the rationale behind their selection provided. The review approach allowed the shipbuilders to concentrate on selected areas of design during a particular period, i.e., hull systems, or machinery systems, etc. thus maximizing their review efficiency.

The purpose of the review was to insure the producibility of the design, explore ways of reducing ship cost by redesign, specification changes, or changes in requirements (i.e., NAVSEA shipbuilding requirements, not TLR requirements). The manner in which the review was conducted also allowed the shipbuilders an opportunity to understand the rationale behind the design and the reason particular items were specified the way they were.. The dialogue also enhanced shipbuilder understanding of the sources of various requirements, i.e., SECNAV, OPNAV, NAVSEA, Congressional direction, etc., and thus which ones might be changed. Over 200 comments were received from the seven participating shipbuilders which should result in considerable cost savings in the design. From a producibility point of view, many items were accepted such as a reduction in camber in many topside areas and a simplification of fuel tank arrangements and associated piping runs.

There were a significant number of suggestions for structural simplifications which would ordinarily be acceptable for Navy auxiliary ships. However, many of these could not be accepted for the AOE because of the high shock requirements for this ship which will operate with the battle group.

The shipbuilders noted that this review strategy limited their comments regarding producibility and cost reduction ideas because the design was already "cast in concrete".

MCM-1

Two shipbuilders, Peterson Builders, Inc. and Marinette Marine Corp., were selected through a competitive source selection process to participate in the contract design phase under Ship System Design Support (SSDS) contracts. Their involvement was designed to facilitate identifying industry recommendations for producibility and cost saving features. It also served to familiarize the prospective shipbuilders with the design to enhance the validity of their ship construction cost proposals. Both contractors maintained offices close to NAVSEA during the design. Due to delays in the Navy contracting process, the contractor support did not start until the last third of the contract design phase. Yet the shipbuilders provided over 600 specification and drawing comments on the design. Of these, 464 were adopted. Peterson was subsequently selected as the lead shipbuilder and, 'later, Marinette Marine was selected as the follow shipbuilder.

DDG-51

Shipbuilder involvement was emphasized throughout the preliminary and contract design phases of DDG 51 to enhance producibility and reduce cost. CAPT Clark Graham: now at MIT, played a key role in the DDG 51 design and is presenting a paper at this Symposium entitled: "Producibility as a Design Factor in Naval Ships", co-authored with LCDR Michael Bosworth.

Seven shipbuilders expressed an interest in participating in the DDG 51 concept and preliminary design phases and did so. The shipbuilders were: Bath Iron Works,

Quincy Division of General Dynamics, Newport News Shipbuilding Co., Lockheed Shipbuilding and Construction Co., Ingalls Shipbuilding Division of Litton Industries, Los Angeles Division of Todd Pacific Shipyard Corp. and the Seattle Division of Todd Pacific. They conducted more than sixty studies involving shipbuilder-proposed alternatives and trade-off candidates.

During the concept design phase, these shipbuilders looked at broad topics, including a review of the current baseline, to identify potential design changes for cost reduction or easier production. Topics studied included an assessment of the effect on acquisition cost of a reduction in molded deck heights and in passageway volume, and analyses of the cost benefits of incorporating various degrees of shipboard data multiplexing, of applying metric standards throughout the ship, and of using a computerized data base for contract design.

During-the preliminary design phase, the shipbuilders looked at the tightness and volume sensitivity of the electronics/controls complex, the machinery box, and the passageways and accesses. Concepts evaluated included:

- o minimum deck heights and widths,
- o modularity of combat system equipment to standardize and simplify installation,
- o minimizing structural depth in way of decks with false floors,
- o recessing the pilot house into the radar complex,
- o vertical distribution of combat system support services using armored trunks,

o mast designs to minimize weight,

o modularity and pre-outfitting of machinery and auxiliary equipment and of piping systems,

o effects of using lightweight cable,

o installation of GRP joiner bulkheads,

o recessing equipment mounted in passageways,

0 mounting equipment , usually outside of the ship, inside to reduce topside maintenance.

Three shipbuilders with current combatant ship construction experience, Bath, Ingalls and Todd, were selected to support the design effort during Contract Design. Each shipyard supplied a four-man team (team leader, weights, system engineering, cost) to work on-site as part of the design team, a feature unique to the DDG 51 design effort at the time. Shipyard personnel rotated in the system engineering slot and came with expertise in structures, combat systems, computers, outfitting, and other specialties as the need arose. Their on-site support included review and evaluation of emerging design data, performance of additional trade-off studies to enhance the producibility of the design, development of cost and weight estimates, trade-offs-of individual systems or components , participation in drawing board. reviews, and attendance at Navy reading sessions and quality assurance reviews of -the specifications and CDRL items .for the initial RFP draft. Participation by shipbuilders in the reading sessions gave valuable insight to the Navy specification

writers as to how the eventual user would interpret the words in the Ship Specifications and the information presented in the drawings.

During the DDG 51 contract design phase, a full time Navy producibility engineer gave focus to the producibility effort and ensured that all concepts and cost saving proposals generated by the shipbuilders were reviewed and evaluated. His responsibilities included coordinating and documenting the information provided by the shipbuilders, identifying specific topics for shipbuilder investigation, and obtaining estimates of cost savings and schedule reductions for proposals submitted.

A bit of design history is interesting to illustrate the difficulty associated with optimizing a contract design for producibility. An effort was made to identify module breaks during the DDG 51 contract design so that space arrangements, equipment layouts, structural configurations and distributive system layouts could be defined with the break locations in mind. However, due to differences between the three shipbuilders* facilities and methods, it was not possible for any two of them to agree on break locations, let alone all three! They agreed to disagree. Consequently, the contract design was completed without any assumed module break locations.

During the DDG 51 contract design, NAVSEA conducted a course on specification preparation. Attendance of the shipbuilders on the DDG 51 team as well as Navy design engineers was encouraged. The course was so well received by the shipbuilder attendees that it was repeated at the shipyards, thereby enabling many more shipbuilder personnel to become familiar with the Navy's practice in preparing specifications and related documents.

References (7) thru (12) contain additional information on the role of the shipbuilders in the DDG 51 design.

LHD-2

The LHD class was selected as one of four Navy Programs to receive special emphasis at the outset of the Acquisition Streamlining Initiative. Accordingly, in February 1985 NAVSEA issued a draft RFP with Specifications and Drawings for the Follow Ship Detail Design and Construction Contract to each potential shipbuilder for review and comment. The purpose of this review was to solicit shipbuilder comments to "tailor" the specifications and drawings to enhance ship producibility, i.e, change the specifications to define the ship in a way to reduce cost, facilitate production, etc., without jeopardizing operational or performance capabilities. A total of 716 questions and comments were received of which 49 were technical or design-related (specification-drawing clarification and interpretation). The comment included proposals to specify commercial in lieu of MIL/FED specifications and to delete certain deliverables. No comments were considered major, probably due to the short time allowed for shipbuilder review.

This concludes a description of how shipbuilders were involved in five recent ship design projects.

Specification/Drawing Flexibility

The T-A0 187 Class oiler design was one of the first Navy ship designs in which the shipbuilder was given flexibility in developing the hull shape and structure. Both the midship section and lines drawing, historically contractual, were issued as guidance documents although the general arrangement was maintained as a contract drawing. The shipbuilder had to satisfy ABS rules, meet speed, design the propeller, and conduct model tests in order to satisfy mission requirements. He was permitted to optimize the design to best meet his own production methods.

Producibility Lessons Learned

NAVSEA engineers receive feedback from SHAPMs, SUPSHIPs, and directly from shipyards regarding producibility problems. We continually look for ways to improve our ship designs to facilitate the use of less costly and easier construction methods. Much feedback comes from official change orders which are screened for application on subsequent designs. During a new design all these lessons learned are considered. Some examples: on a new design the deck heights are studied to ensure they are adequate to readily arrange and install ductwork, equipment, etc. Straight, in lieu of parabolic, camber has been used as a result of feedback from shipyards. The structural designers over the years have reduced the number of different sizes of stiffeners to save costs, based on comments provided by shipyards. Machinery arrangements consider problems with construction and maintenance access. Many functional codes have developed internal guidance documents for design so that such lessons learned can be applied to future designs.

Models and Mock-ups

During contract design, NAVSEA often develops scale models to determine machinery arrangements, complex pump room layouts, piping runs, etc. to assure producibility and maintainability. Full scale mock-ups are generally done during detail design and NAVSEA specifies the requirement in the ship specifications. Though primarily used in assessing operating and maintenance aspects, mock-ups are invaluable tools for producibility studies too, especially in machinery design and submarine tank construction.

Specifications and Standards

A consensus has developed that a complete set of National Shipbuilding Standards

is needed to support a competitive U. S. shipbuilding industry. A program to accomplish this has been developed and is underway. The SNAME Ship Production Committee Panel SP-6 establishes Program policy and ASTM Committee F-25 on Shipbuilding is developing the Standards. The program is described in Appendix C of Ref. (1). The Navy actively supports this program with the objective of converting many existing Milspecs and other Navy standard documents to commercial industry standards. An approach has been adopted to deal with unique Navy requirements in a particular area which simply cannot be incorporated into a broadly acceptable commercial standard. The approach is to develop Navy or DOD Addendums to the industry standards. Problems associated with the program from the Navy's perspective are its manpower requirements and the length of time required to develop and issue agreed upon standards.

Three other NAVSEA spec-related programs are notable. We are planning major emphasis on the Specification Improvement Program with the objective of ensuring that NAVSEA cognizant specifications, standards, and standard drawings are current with the state of the art and remain up-to-date. The program has been underway for several years. Each year the documents needing revision are prioritized and the most urgent ones are rewritten or updated to the extent funds are available. As of September 1985, of the 8200 documents for which NAVSEA is responsible, 1100 are being revised and 2100 require major revision and haven't yet been acted upon. FY 85 funding for the Program totalled about 812M.

Another NAVSEA effort which has been started is the development of a so-called "Commercial Gen Spec". Such a document would facilitate the development of tailored specifications for NAVSEA ship designs based wholly or extensively on commercial standards and practices. In the past in such cases, NAVSEA has attempted to use the MARAD Gen. Spec. as a basis for spec preparation but this has proven to be unsatisfac The format of the MARAD specification does.not correspond nearly as well to the NAVSI

engineering organization as does the Ship Work Breakdown Structure (SWBS) of the Navy Gen Spec. Thus, in assigning responsibility for specific sections of the MARAD spec, there are many "split" sections. This leads to confusion and some important aspects inevitably fall through the cracks. Another problem is that the MARAD Gen Spec has not been kept current with technological advances and recent changes in shipbuilding practices. NAVSEA management has identified initial funding and in-house manpower to execute this program. Estimates are that about $200K will be required to develop the initial version of the document and about $100K per year thereafter for maintenance and updates. So far, a first draft of the document has been created.

For the past two years NAVSEA has been working on an in-house project to identify and highlight our most critically important ship design standards--those principles deemed most vital to ship effectiveness, safety, operability, maintainability and survivability. The idea is to make these standards highly visible to our executives, acquisition and design managers and the engineering work force so that it is less likely that they will be overlooked or overruled by the direction of a mid-level design or acquisition manager. The standards are purposely succinct and quantitative--a sort of "Ten Commandments" of NAVSEA ship design. In many cases they reference more extensive specifications, Design Data Sheets, Technical Practices Manuals or other pertinent information. To date, 36 design standards have been approved covering such topics as longitudinal hull strength, ship service generator sizing and selection, freeboard and anchor system sizing and selection.

Computer Supported Design

The NRC report "Toward More Productive Naval Shipbuilding", Ref. (1), recommends the Navy should ". ..employ electronic media to a maximum extent in design, construction management and life-cycle support in the next generation of Naval ships." (P. 6)

"Employ electronic media to a maximum extent in design" is a pretty fair synopsis of the mission of the Computer Supported Design (CSD) Project which its Director, Mr. Kit Ryan, will describe in another paper at this symposium.

The Computer Supported Design (CSD) Project was established about two years ago by NAVSEA to develop a fully integrated, computer-based ship design system. The system is to permit the development of ship designs from conception through the end of the contract design phase. The original objective was to develop the system in five years but more time will be required due to funding shortfalls. Progress to date has been slow but encouraging.

There are substantial parallels, especially in the configuration definition area, between computer applications for design and computer applications for construction and life cycle management. Since the latter is also a SEA 05 responsibility, CSD has been active in establishing the technical and contractual mechanisms for data transfer by working with Navy and industry representatives, particularly in association with DDG 51 and SSN 21 design efforts.

Computer systems available today offer a means of design communication which is significantly more complete and less ambiguous than the engineering drawing. To appreciate this change, one needs only to consider the improvement in communications quality of the engineering drawing as compared to its predecessor, the written or verbal instruction.

As with many aspects of modern life, this change has arrived with stunning speed. CAD models reflecting any part of the design can be generated today on many computer systems. Furthermore, a number of systems have the capability to

reflect many attributes and connectivities at a near-product-model level of definition. The Initial Graphics Exchange Standard (IGES) currently offers a substantially complete method of communicating the geometric portion of these models between systems and promises to be expanded into other areas of the product model transfer.

CAD system costs are rapidly diminishing. Knowledge of how to integrate these systems into the design process is rapidly growing and spreading. CAD models will be the routine method of reflecting design integration within four years and product models will be standard within eight.

The CSD Project Director, Mr. Ryan, is an active member of the CAD Panel of the SNAME's Ship Design Committee. This Panel is our principal vehicle for interfacing with industry regarding the CSD project development. Virtually all ship design agents and shipbuilders are represented.

Industry Interfaces

NAVSEA actively supports the efforts of the Technical Committees of SNAME to improve the productivity of the U. S. shipbuilding industry, to improve our ability to design ships and to enhance the integration of ship design with production. NAVSEA is represented on both the SNAME Ship Design and Ship Production Committees as well as all of their Panels concerned with issues of interest to NAVSEA. Pertinent to this discussion is our membership on the Ship Design Committee's Panel SD-Z (Computer-Aided Design) and the Ship Production Committee's Panel SP-4 (Design/ Production Integration) and SP-6 (Standards and Specifications) as well as ASTM Committee F-25 on Shipbuilding and its technical subcommittees (the latter are involved in the National Shipbuilding Standards Program). We would welcome invitations for further participation in areas where that is deemed desirable.

Ship Design Support

During the past two years, NAVSEA has implemented a new approach to contracting for ship design support. The thrust behind this initiative has been to improve the quality of our ship designs and, at the same time, to increase the competition for ship design support work (i.e. eliminate sole source tasking). In the past we have had identical Level of Effort type contracts with a large number of firms to provide ship design and other engineering support on a task basis. In principle, tasks were to be competed among the firms but, in fact, most tasks were processed on a sole source basis since less administrative lead time was required (4-6 weeks vice 6-10 weeks for competitive tasks): The primary disadvantages of this approach were the high percentage of sole source tasks and the lack of continuity in contractor support, i.e. a specific type of work was tasked to many different firms at different times depending upon workload, individual task leader preferences, etc. The effects of this lack of continuity were that product quality suffered due to the lack of sustained "lessons learned" feedback. Also, inordinate amounts of time were spent by Navy engineers in training contractors.

Under the new approach, competition takes place "up front" for pairs of contracts awarded in each major functional area of the Ship Design and Engineering Directorate. The number of firms providing support in a given functional area is reduced to two prime contractors and they do <u>all</u> of the work, i.e. fleet support as well as new ship design, detail design and construction support, and modernization/conversion design. Thus training is facilitated, the contractors are exposed to <u>all</u> fleet feedback and the reflection of this feedback into our ship design and modernization efforts is enhanced. Sole source justifications are eliminated; the Technical Manager of each pair of contracts decides which firm is to be assigned a specific task without needing to justify his decision to higher authority. Incidentally, one pair of these contracts provides for design

integration support and also enables us to contract with a single firm for an entire preliminary and/or contract design of a so-called "Lo Mix" ship. Such designs are straightforward designs of a T-ship or Navy auxiliary ship or service craft where we don't want to involve the entire engineering organization due to the press of higher priority engineering work.

Fleet and INSURV Participation in Ship Design Reviews

For many years it has been standard procedure to solicit Fleet comments on the contract design specification and drawing package prior to completion. Recently, it has been found that this procedure alone is inadequate. Fleet commentors have been handicapped by a lack of understanding of the design requirements and critical design issues and how they were resolved. Faced with the sudden delivery of a huge package of specifications and drawings without adequate explanation, it might be expected that the comments received would tend to be relatively minor ones, prepared by a low ranking staff member. In order to enhance the substance and hence the value of Fleet design review inputs, efforts are now routinely made to provide briefings on the design to key Fleet personnel prior to soliciting review comments. Also Fleet representatives are invited to NAVSEA design team reviews as well as Independent Design Reviews. The Fleets have responded well to these initiatives and on recent designs Fleet comments of great value have been received. Three recent examples are:

LHD-1 Fleet Reviews

Fleet representatives were invited to attend and participate in a series of "In-Process Design Reviews" throughout the contract design phase (one every 6 weeks). COMNAVSURFPAC and COMNAVSURFLANT representatives, as well as COMPHIBGRUWESTPAC,

COMTACGRUTWO, COMPHIBGRU TWO and various ship operators, including the CO and X0 of an LHA, attended. The Fleet Representatives questioned various design decisions and provided first hand ship operating experience and suggestions to change design features that were marginal or "bad actors" in the fleet. This face-to-face review between NAVSEA, the Fleet and the shipbuilder proved to be very valuable.

A "Lessons Learned" document was developed which identified over 250 reports of LHA deficiencies (i.e. various Fleet reports, CASREPS, etc). This document was updated to reflect comments received from the Fleet during the In-Process Contract Design Reviews. This document was incorporated in the Contract Design and Detail Design Contracts for shipbuilder action, to resolve and report corrective actions taken to NAVSEA. These reports were included in the ISD In-Process Design Reviews.

AOE-6 Fleet Review

An independent design review was performed during the contract design phase. The ten Fleet members of the review team represented SERVGRUONE, SERVGRUTWO, NAVSURFLANT and NAVSURFPAC. A number of excellent comments were received and many were incorporated as shown in the following Table:

	Incorporated	Partial/Pending	Rejected	Total
Major Comments	11	4	3	18
Significant Comments	8	5	2	15
General Comments	42	'14	11	67
	61	23	16	100

Details are provided in Ref. (13).

DDG-51 Fleet Review

A formal Fleet review of the DDG-51 contract design was conducted in mid-April 1984 with CINCLANT/PAC and SURFLANT/PAC participating. The contract design spec and drawing package was provided to the reviewers beforehand. The review was a success in that the Fleet representatives gained a much better understanding of the design and, in turn, made a number of useful suggestions for improvements.

INSURV Design Reviews

Early in 1983, a new initiative was undertaken by NAVSEA and INSURV. This was to have INSURV review Navy ship designs on-site prior to award of the ship construction contract. Previously, INSURV had always been asked to review completed contract designs without interfacing with NAVSEA engineers. Lacking knowledge of the design history and rationale for many design decisions, the INSURV comments were generally of limited value. With the greater knowledge that comes from face-to-face meetings, it was felt that INSURV's familiarity with the problems of our operating Fleet would make their review comments especially valuable. This has proven to be the case.

LHD 1 was selected to be the first ship to be reviewed on-site by the INSURV Board during the Contract Design Phase. INSURV produced 497 action items as a result of their analysis from 16 to 20 May 1983. Many of these items resulted in modifications to the design, others were earmarked for action during the detail design phase and were invoked as part of the detail design and construction contract.

This initial review was followed by an INSURV review of the DDG 51 contract design. The December 1982 preliminary design baseline was informally reviewed

in March 1983, the INSURV review team received a two-day informational brief on the contract design in Sept. 1983 and, finally,-the completed contract design was formally reviewed during the week of 2 April 1984. As a result of the latter review, 268 recommendations were made, of which 175 were adopted.

Most recently the MSH design, developed by Bell-Halter, was reviewed in June, 1985. Again, a number of valuable comments were made.

The INSURV design reviews have proven to be an especially effective way to interject "lessons learned" from numerous inspections of the full spectrum of Navy ships into new ship designs before they are completed.

Increased SEA 05 Role During DD&C Phase

As previously mentioned, Ref. (6) established as Command policy that the Ship Design and Engineering Directorate would exercise increased technical control during the detail design and construction phase to ensure that design standards and requirements are being met by the shipbuilder. As a result of this direction, the number of CDRL deliverables to be reviewed and approved by NAVSEA instead of the Supervisor of Shipbuilding is substantially increased on the DDG 51 over previous designs. For example, the following Table contrasts DDG 51 with CG 47:

Number of Deliverables

	CG 47	DDG 51
NAVSEA Review.(1)	295	639
NAVSEA Approval	166	401

(1) Total, including deliverables for approval

There will also be increased Engineering Directorate involvement in design reviews, especially in the areas of interior communications and combat system integration.

5. Issues

Based on the preceding discussion, three issues related to the ship design,/ production interface appear to be worthy of note. These are:

- o Specification philosophy
- o Approach to shipbuilder involvement in PD/CD
- o Degree of Contract Design definition

Specification Philosophy

For many years, most naval ship specifications have been based on the General Specifications for Ships of the United States Navy, i.e. Gen Specs. This document has evolved over the years as lessons have been learned, often harsh ones, and technology has advanced. Gen Specs is a mix of "detail" and performance-type. specification requirements; in many instances, a successful way of doing something has been found, along with many unsuccessful ways, but no one has been smart enough to write a performance specification which would embrace the successful method but exclude the known unsuccessful ones. Gen Specs is generic and broadly applicable to the full spectrum of naval ships; it is carefully tailored to each specific ship during the ship's contract design phase. Gen Specs and tailored ship specs based upon it typically invoke a large number of lower tiered specs and standards which have similarly evolved over time to reflect lessons learned and technological advances at the system and equipment level.

The guidance received to date concerning the DOD acquisition streamlining initiative is apparently at odds with our traditional approach to developing naval ship specifications. Such injunctions as "use a clean sheet of paper approach", "eliminate the automatic chain referencing of lower tier specifications", "question all requirements" and "minimize 'how to' specifications", all would appear to suggest that the Gen Specs approach is no longer deemed acceptable.

Another apparent specifications conflict arises as a result of one of the major thrusts of the comments and recommendations made in Ref. (1) that our contract design baselines must be firmer, i.e. specifications must be more detailed. Again, "firmer contract design baselines" would appear to be at odds with the acquisition streamlini injunctions of "don't overspecify", "use a clean sheet of paper approach*', etc.

Considerable attention is being given to these apparent conflicts within the Navy's ship design and acquisition community at this time. Note the use of the word "apparent". The authors are optimistic that, in fact, there are fewer contradictions in this area than might first appear to be the case.' Indeed we believe that much good will come from the current soul searching and debate. We cannot walk away from the hard won knowledge reflected in the Gen Specs, knowledge often won at the expense of American sailors' lives, but at the same time we cannot afford to blindly lock ourselves in to archaic or simply unnecessary requirements when a fresh look would show that modern technology will permit a fully satisfactory and more cost-effective solution. The acquisition streamlining injunctions are telling us that we must take that fresh look in all of our current and future designs.

Approach to Shipbuilder Involvement in PD/CD

As discussed earlier, in recent years, shipbuilders have routinely participated

in the contract design and, less frequently, in the preliminary design of Navy ships. In the authors' view, a prime motivator for this involvement was a desire to defuse the adverserial relationships (and claims) which characterized naval shipbuilding during the 1970s. Whatever the rationale, there are three potential generic advantages to increased shipbuilder involvement:

o To incorporate producibility considerations into the design in order to reduce construction costs.

o To gain insight into the shipbuilders' interpretation of the specification language in a non-adversarial setting in order to reduce ambiguity. A very worthwhile objective, but also, candidly, a "claims avoidance" tactic.

o To improve the overall quality of the design by exposing it to critical review by outside experts.

The above advantages pertain mainly to shipbuilder involvement during ship designs conducted by NAVSEA. In addition, the coin can be reversed, and the ship can be designed by industry, with varying degrees of NAVSEA involvement. Each of these approaches has pluses and minuses (and proponents and opponents), and there is likely no textbook solution applicable across the board.

From the producibility standpoint, the authors have not seen clear evidence that shipbuilder involvement in early stage (preliminary) design is necessary; The Ship Production Committee's Panel SP-4 "Design for Production Manual" Ref. (14), has numerous examples of how to reduce ship cost by designing for producibility. The examples are a mixture of early stage and detail design considerations. However, the early stage design considerations are broad concepts which can be applied based

on design guidelines, and do not require shipbuilder involvement in specific designs. We support the need for the Navy to apply producibility considerations in early stage design and we need the shipbuilding industry to tell us what these considerations are. But, that is not a sufficient basis for arguing that direct shipbuilder involvement in specific preliminary designs is essential.

In the authors' view, NAVSEA will continue to design the majority of the Navy's ships, and the principal issue to be determined in each specific design will be the range and depth of the shipbuilders' involvement. Whichever approach is "best" for an individual design is a function of a number of variables.

The approach used on MCM and DDG-51 was to competitively select a relatively small number of shipbuilders to assist NAVSEA in the contract design effort. Since competition for the lead ship detailed design and construction contract would be restricted to these shipbuilders , each of them was motivated to really dig in and become highly knowledgeable about the design. Typically, this approach produces excellent suggestions to improve both the quality and the producibility of the design. From the shipbuilders' vantage point, even if they did not win the lead ship contract, they-would still be in an excellent position for a follow ship award. Disadvantages of this approach include increased design *costs* (hopefully, more than compensated by construction savings), and the time required to competitively select the shipbuilders (this can be done in parallel with the NAVSEA preliminary design effort). This approach is also consistent with the NRC study (Ref. 1) recommendation to reflect the lead and follow shipbuilder's inputs in the contract design.

Another approach is to invite a larger number of shipbuilders to participate, and to only partially compensate them for their efforts. This technique is usually employed for those less complex ships where the number of potential shipbuilders

is relatively large, e.g. T-AO 187 employed this approach. From the Navy's viewpoint, this approach is administratively quicker to put in place, and it is cheaper, at least in near term costs. And it is of course to the potential bidders' advantage to gain early insight into the Navy's design. But it can be argued whether or not this approach has the potential to achieve the three goals listed above. Market place factors will likely determine the degree of shipbuilder involvement.

Another concept, currently being employed in the SWATH T-AGOS design, is to invite ALL interested shipbuilders to participate in the NAVSEA design effort at their own expense. In the case of SWATH T-AGOS, the shipbuilder representatives are actually working members of the ship design team. This is not a prerequisite for lead ship award, but the number of interested shipyards is still high. SWATH T-AGOS may be a unique case because of the desire to get in on the "ground floor" in view of the Navy's current great interest in SWATH ships , and because of the very large number of shipyards capable of constructing this "low tech" ship. A variant of this approach was employed in the case of AOE-6, where shipbuilder participation was restricted to a review/comment mode only. Participation by industry was excellent and produced good results, with minimum cost and schedule impact to the Navy. However, the shipbuilders felt that their comments could only be minor and have limited impact since the design was already "locked-in".

Involving all interested shipbuilders as working members of the design team will certainly cause ship producibility considerations to be given greater weight than simply requesting them to review and comment on an essentially complete-design. However, the design cannot be tailored to the unique inputs of the potential lead and follow shipbuilders (since all potential builders can participate) and there is a real possibility that a shipbuilder with no real chance of winning the construction

contract might bias the design unfavorably from the ultimate winner's point of view simply because of his influence on the area of design he worked on.

A more sweeping approach is to pay the shipbuilder (or shipbuilders) to actually conduct the contract design (and perhaps even the preliminary design), but under Navy direction and control. Such contracts can be awarded competitively (a lengthy process) or sole source if unique capabilities are required. In this approach, the shipbuilders are fully compensated, and are obviously in a good position for award of lead or follow ships. There is additional design cost for the Navy if more than one shipbuilder is involved and additional time may be required for the Navy to produce its own design (incorporating the "best" features of the individual shipbuilder designs which the Navy now "owns"). While the Navy is able to exercise control over the design, the shipbuilders are also relatively free to innovate and incorporate producibility considerations which may be unique to their facilities. Each party therefore has a feeling of "ownership" of the design, and this approach has many advantages to offer.

A more radical approach is to turn the design totally over to industry with essentially no Navy control or oversight. In essence, this is the ultimate "performance spec" approach. A phased competition takes place with the number of competitors successively reduced until one ultimately emerges as the winner. Under this concept, industry is encouraged to innovate to the maximum extent possible, and (in some quarters) this is perceived as leading to major cost savings with no reduction in warfighting capabilities. However, when competing designs are produced by industry, the prohibition against ANY Navy involvement (for business reasons) has the potential for design deficiencies to be introduced. There is the potential that, in order to reduce acquisition costs, less attention will be paid to ship attributes such as reliability and maintainability, which are

difficult to quantify in a performance specification. NAVSEA will then be faced with correcting problems identified by INSURV and the Fleet.

Finally, there is a procurement strategy called the "two step", which has been frequently employed for the design and construction (or conversion) of relatively non-complex ships. Interested shipbuilders respond to a Circular of Requirements with their own designs and also build proposals (not paid for). The lowest bidder who satisfies all requirements is awarded the detail design and construction contract. This approach is best suited for cases where the technical risk is low. It is frequently employed to free NAVSEA design personnel to work on more complex warships. Another argument which is frequently voiced is that only industry can produce a "commercial design". Regardless, this approach motivates industry to incorporate cost savings, since the construction contract will be awarded to the lowest bidder whose proposal meets the Navy's stated requirements.

As discussed above, the Navy employs numerous approaches to involve the shipbuilder in the design process: everything ranging from the shipbuilder looking over the shoulder of the Navy ship designers to industry actually doing the designs with minimal Navy oversight. Our goal - cheaper and better ships - can and has been realized, and it seems clear that shipbuilder involvement will continue to be the accepted way of doing business. But the number of potential options is high, and the degree and the method of involvement which is "best" for any specific ship acquisition must be decided on a case basis.

Degree of Contract Design Definition

This issue also relates to the apparent contradiction between the National Research Council (NRC) study recommendation that the contract design baseline be firmer and the Acquisition Streamlining Initiative's injunctions whose collective

thrust is: specify less, take more risk, give industry more room to innovate and thus reduce cost. One of the implications of the zone-oriented ship construction approach is that ship design definition must be done earlier and more thoroughly. It must also be integrated with the ship production process. This is what led to the NRC recommendations to incorporate production considerations in the preliminary and contract design phases, reflect lead and follow yards' inputs in the contract design, e.g. facilities, suppliers and production methods, and produce a firmer design baseline at the end of CD. The NRC recommended that more emphasis be placed on system design and equipment selection in CD and less emphasis on structural detailing and space arrangements. Also, that the number of contract (non-deviation) drawings be minimized.

These NRC recommendations are generally endorsed and in fact are consistent with other recent events. One of the conclusions of an extensive study of naval ship weight growth during design and construction, which was completed a year or so ago, was that the distributive systems were the area where most unanticipated weight growth occurred and that more emphasis must be put on earlier design definition for these systems, i.e. during CD. We expect that, with the aid of advanced computer-based analysis and graphics tools, more distributive system design will be done during the CD phase in the future. Of course, there is no point to such effort if the lead shipbuilder is not tasked to build upon the system definitions established during CD rather than starting from scratch. In other words, when the desired definitions are established in CD, they must be further developed during the detail design phase, i.e. they must be specified in the completed CD package. This additional specification detail would be reasonably consistent with the acquisition streamlining injunctions only if the acquisition strategy followed were such that the prospective lead and follow shipbuilders actively participated in the CD effort. Only in that way could

the shipbuilders effectively influence the distributive systems' designs from a producibility standpoint. The DDG-51 acquisition strategy is an example of this approach.

6. Conclusions

This paper has focused on the interface between naval ship design and production and on current events, topics, initiatives and issues related thereto. Interest in this interface is at a peak these days primarily for two reasons. First, it is widely recognized that productivity improvements and hence ship cost reductions are dependent to a considerable degree on decisions made during design, not just in the detail design phase but also in earlier phases. Second, it is recognized that increasing threats make it essential that our new ships be fully effective, which means that they must be operable, reliable, maintainable and survivable as well as possess the desired mission capability. A necessary prerequisite is that a ship design reflecting these attributes be developed and reviewed by capable and experienced engineers prior to production.

Based on the information in the paper and its references, the authors' conclusions are:

- Navy engineers involved in ship design and acquisition must be educated in zone-oriented ship construction technology. Formal training is necessary as well as the informal , on-the-job variety (NRC recommendation), This must be done promptly. The Ship Production Committee should take the lead in organizing appropriate curricula for executives, mid-level managers and working level designers and engineers.

o Navy and industry must collaborate in developing computerized approaches to ship design, construction, life cycle support and management, including data transfer techniques (NRC recommendation). Efforts to this end are underway.

o Means must be developed to incorporate production considerations in the preliminary and contract design phases. Educating Navy engineers and involving shipbuilders in these phases (at least in contract design) will go a long way. The development of producibility and manufacturing cost design guides to aid preliminary and contract design teams to develop more producible and cost effective designs is also needed (NRC recommendation The Ship Production Committee should also take the lead in this area.

o The best approach for each of the three issues discussed in the preceding section is dependent on the specifics of particular situations:

- Specifications tiering can be reduced and performance emphasized. Certainly the development of National Shipbuilding Standards with emphasis on commerciality should be accelerated. However, we cannot afford to suddenly abandon the Gen Specs and it's myriad, hard earned, lessons learned.

- Many options are available for involving shipbuilders in contract design and even earlier. The best choice is dependent upon many factors as applicable to each specific case. As Navy ship designers we believe that for complex ships (including warships, amphibious, mine and MLSF ships which steam with the Battle Group) the best approach is generally

a Navy design effort in which two, or at most three, competitively selected shipbuilders actively participate as design team members during contract design. The competition for lead ship award should be restricted to these active participants. We have seen no hard evidence that shipbuilder involvement in the preliminary design phase is essential. Design guides should be sufficient to incorporate producibility considerations at this stage of design. For relatively simple ships, a shipbuilder design approach is generally best, either a phased, funded design competition or a Z-step procedure for the simplest cases.

- There are good arguments for increasing the level of detail addressed in contract design, specifically in the distributive systems. The need for better weight estimates and the requirements of zone-oriented construction. are both pushing us in that direction. Advanced computer-aided design tools to define and analyze these systems, when available, will enable us to accomplish this. We expect that within five years, distributive systems will be routinely designed in the CD phase.

References

(1) "Toward More Productive Naval Shipbuilding", Committee on U. S. Shipbuilding Technology, Marine Board, Commission on Engineering and Technical Systems, National Research Council, National Academy Press, Washington, D. C., 1984.

(2) Weiers, Bruce J., "The Productivity Problem in U. S. Shipbuilding", Journal of Ship Production, 'Vol. 1, No. 1, Feb. 1985, pp 7-28.

(3) CAPT Robert C. Baker, USN and CDR Michael R. Reed, USN, "Twenty Steps to a Better Fleet: INSURV Review of Surface Ship Design Engineering'*, Naval Engineers Journal, March 1985.

(4) "Navy Acquisition Streamlining" by G. C. Hoffmann, presented at 2nd IES Workshop on Tailoring-Applications of the DOD Streamlining Initiative in Acquisition Programs, June 1985.

(5) ASN (S and L) Memorandum dated 8 August 1985, Subject: Dept. of the Navy Program Plan for Acquisition Streamlining.

(6) Vice Commander, Naval Sea Systems Command Memorandum dated 1 May 1984, Subject: Long Range Hull, Mechanical and Electrical Engineering Objectives of NAVSEA.

(7) DDG 51 Guided Missile Destroyer, Preliminary Design History, June, 1984.

(8) DDG 51 Guided Missile Destroyer, Contract Design Management Plan, Volume 1, 20 July 1983.

(9) DDG 51 Guided Missile Destroyer, Contract Design History, January, 1985.

(10) Johnson, R. A. MNaval Ship Design: The Shipbuilders' Emerging Role", Naval Engineers Journal, Volume 97, Number 4, American Society of Naval Engineers, Inc., May, 1985.

(11) DDG 51 Shipyard Producibility Team Presentation, Drawing Board Review, 26 May, 1983.

(12) Training Course, Preparation of Specifications and Standards, NAVSEA, 1985.

(13) Naval Sea Systems Command, "AOE-6 Independent Design Review Report", 15 March, 1984.

(14) SNAME Ship Production Committee Panel SP-4, "Design for Production Manual'*, 1985,

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